Determination of Instrument Landing System (ILS) Glidepath Angle, Reference Datum Heights (RDH), and Ground Point of Intercept (GPI)

1. PURPOSE. This order prescribes the method by which the actual flight inspection glidepath angle, instrument landing system (ILS) reference datum height (RDH), achieved ILS reference datum height (ARDH), and ground point of intercept (GPI) are determined.

2. DISTRIBUTION. This order is distributed to the branch level in the National Procedures Office and Flight Inspection Operations Division in Aviation System Standards, to the branch level in the National Airway Systems Engineering Division, Washington headquarters; to the branch level in the regional Airway Facilities and Flight Standards divisions; to the Flight Inspection and Procedures Branch, FAA Academy, Mike Monroney Aeronautical Center; to the International Flight Inspection Office; all Flight Inspection Offices; and special military addressees.

3. CANCELLATION. Order 8240.47A, Determination of Instrument Landing System (ILS) Glidepath Angle, Reference Datum Heights (RDH), and Ground Point of Intercept (GPI), dated May 1, 1992, is canceled.

4. BACKGROUND. Prior to the inception of this Order, the documented threshold crossing height (TCH) ground point of intercept (GPI) were calculated procedural values based on ground geometry. The revised inspection methods contained in this order will analyze glide slope performance based on actual achieved results, not theoretical values. The methods presented provide flexibility in siting glide slope facilities while preserving the critical aspects of assuring adequate wheel crossing heights at the threshold. This revision includes changes to some definitions, defines when this order should be applied, clarifies required procedural actions, authorizes the use of achieved ILS RDH (ARDH) for certain glide slope facilities, and authorizes the application of this order on U.S. military glide slopes.

5. EXPLANATION OF CHANGES. This revision includes the following changes:

a. Paragraph 6d: Redefines glide slope origination point.

b. Paragraph 6e: Redefines aiming point.

c. Paragraph 7d: Adds requirement for site improvements resulting in elevation changes.

d. Paragraph 7e: Redefines application for Category I facilities.

e. Paragraph 7f: Clarifies end fire glide slope application.

f. Paragraph 9a: Redefines aiming point coordinates when using AFIS**.**

g. Paragraph 9d: Defines skew and adds Figure 1.

h. Paragraph 11a: Clarifies Category I wheel crossing height requirements.

i. Paragraph 11b: Clarifies Category II and III RDH requirements.

6. DEFINITIONS

a. Best Fit Straight Line (BFSL). A straight line segment of the glidepath derived by using a least squares mathematical technique. The slope of this straight line defines the height of the glidepath angle relative to the approach surface baseline and threshold. Upon application of this order, the BFSL in ILS zone 2, projected through the threshold to the runway surface, becomes the RDH reference.

b. ILS Reference Datum Height (RDH). The height of the commissioned glidepath located vertically above the runway threshold. It is derived by computing the glidepath between points "A" and "B" and by projecting an extension of this glidepath to the threshold. The RDH value replaces the mathematical procedural TCH value when this order is applied. RDH is synonymous with the ILS reference datum as defined in the International Civil Aviation Organization (ICAO) Annex 10.

c. Achieved ILS Reference Datum Height (ARDH). The height of the commissioned glide path located vertically above the runway threshold. It is derived by computing the glidepath between 6,000 feet and point "C" and projecting the downward extension to the threshold. The ARDH is influenced by changes in glide path structure close in, consequently the ARDH value may not agree with the RDH.

d. Glide Slope Origination Point. A point defined by latitude and longitude corresponding to the electromagnetic phase center of the glide slope antenna array.

e. Aiming Point. The selected reference coordinate origin defined by latitude and longitude used for glide slope measurements. The aiming point need not be coincidental with the glide slope origination point. Upon application of this order, the flight inspection determined elevation becomes the reference aiming point elevation and is to be used for procedural evaluations and computations.

7. APPLICATION. This order shall be used to establish the glidepath angle, RDH, ARDH, and GPI for all civil and military glide slope facilities proposed to provide Category II/III approach minimums. Paragraphs 7a, 7b, 7c, and 7d define those conditions that shall require application of this order for all Category II/III facilities, as well as any Category I facilities proposed to support Special Category II/III type approaches. Paragraph 7e may be applied for all other Category I type facilities at the discretion of flight inspection or the facilities maintenance personnel.

a. Site, commissioning, and initial categorization inspections.

b. Reconfiguration or special inspections as a result of a glide slope site relocation.

c. A change to the glide slope antenna configuration (null reference to capture effect, etc.)

d. Site improvements which change the documented aiming point or threshold elevation by more than 3 feet.

e. To establish a flight inspection aiming point for CAT I glide slopes when:

(1) All the requirements for Category I glide slope commissioning are satisfactory in accordance with FAA Order 8200.1A, United States Standard Flight Inspection Manual, Section 217.

(2) The flight inspection derived RDH meets the criteria of Order 8260.34, Glide Slope Wheel Crossing Height Requirements, paragraph 5. Facilities not meeting these requirements shall be restricted for use below the decision height. This is to preclude use of the facility for Special Category II/III type approaches.

(3) Procedural review does not identify new obstacle penetrations or require a waiver to Order 8260.3, United States Standard for Terminal Instrument Procedures (TERPS), Chapter 9, ILS.

f. End Fire Glide Slope. Initial reference aiming point elevation corrections exceeding $\pm$ 3 feet shall be reported to the installation engineer. The End Fire Glide Slope is an adjustable angle array which can be adjusted to achieve BFSL results without changing the aiming point elevation (AFIS glide slope height) on the ILS facility data page. Engineering personnel may request a normal transverse structure evaluation in lieu of an approach to establish adjustment references. Changes to site elevation for use as the AFIS aiming point elevation shall only be accomplished by coordinating with the facilities engineering personnel. Following adjustments, conduct additional AFIS approach evaluations.

8. COMMISSIONING SEQUENCE. Facilities engineering, flight standards operations, and procedures personnel shall agree on the **proposed** glidepath angle, TCH, and GPI when a location has been selected for a glide slope installation. These values will be based on operational requirements, obstruction considerations, and siting constraints.

a. Engineering. Evaluate siting conditions and install the antenna at a position which should provide a glidepath conforming to the **proposed** values.

b. Procedures Development. Procedures will make the initial evaluations and calculations using the installation values referenced in paragraph 8a. If the flight inspection derived aiming point elevation exceeds $\pm$ 3 feet of the original aiming point elevation, a procedural re-evaluation of the TCH, GPI, and the final approach obstacles is required. Upon application of this order, the flight inspection derived RDH values shall replace the calculated TCH value for the procedure under evaluation.

c. Flight Inspection. When engineering has installed the glide slope and it is ready for evaluation, check the glidepath and determine the actual angle, RDH, GPI, and ARDH using the BFSL procedures in this order. When the initial aiming point elevation used during the flight inspection evaluation changes by more than ± 3 feet, AMIS data shall be updated to reflect the flight inspection derived reference elevation. Notify procedures of any changes to the initial reference elevation, as well as the RDH and GPI associated with the new elevation. A procedural review of the proposed values will be accomplished using the flight inspection derived data. If the changes result in an obstruction penetration, RDH (TCH) problems, facility restrictions, etc., the glide slope antenna may have to be relocated to a more optimal position. Facilities not meeting RDH requirements for Category II/III use but that are satisfactory in accordance with FAA Order 8200.1A, Section 217, shall be commissioned as Category I until a waiver is issued or the problem corrected. If the ARDH meets Category II/III RDH requirements and all other requirements for Category II/III glide slope commissioning are satisfactory in accordance with FAA Order 8200.1A, Section 217, use of the ARDH to meet the RDH requirements may be requested as a waiver. The waiver will require concurrence by the Flight Inspection Operations Divison, AVN-200, and the Technical Programs Division, AFS-400.

9. FLIGHT INSPECTION PROCEDURES FOR AN AUTOMATED FLIGHT INSPECTION SYSTEM (AFIS).

a. Programming the AFIS. Program the glide slope latitude (GLA) and glide slope longitude (GLO) to coincide with the glide slope origination point. Program the GS-OFF to the glide slope distance offset from runway centerline. Program the glide slope height (GS-HGT) to coincide with the elevation documented on the AMIS facility data sheet as CL-ELEV-ABM, which corresponds to the elevation on centerline abeam the glide slope. All elevations, including the final RDH/ARDH, shall be rounded to the nearest foot in accordance with Order 8200.1A, paragraph 303.2b. RDH/ARDH rounding to achieve tolerance is acceptable, provided all Category II/III glide slope angle and structure parameters are satisfactory in accordance with the requirements of Order 8200.1A, Section 217. The final AFIS data shall be the reference data for all subsequent glide slope flight inspections.

(1) For glide slope facilities with unusual siting characteristics, engineering/installation personnel may request to modify the glide slope origination point as referenced in FAA Order 8200.1A, United States Standard Flight Inspection Manual, paragraph 217.24. This request shall only apply to Category I type glide slopes evaluated in accordance with paragraph 7e of this order. Deviations shall be approved by the Flight Procedures and Inspection Division, AVN-200. This information shall be documented in the FAA Aircraft Management Information System (AMIS) facility data files.

(2) An alternative method of computing the initial reference elevation if no other source is available may be accomplished as follows:

(a) Add the proposed TCH to the threshold MSL elevation.

(b) Multiply the tangent of the proposed commissioned angle by the aiming point distance to threshold.

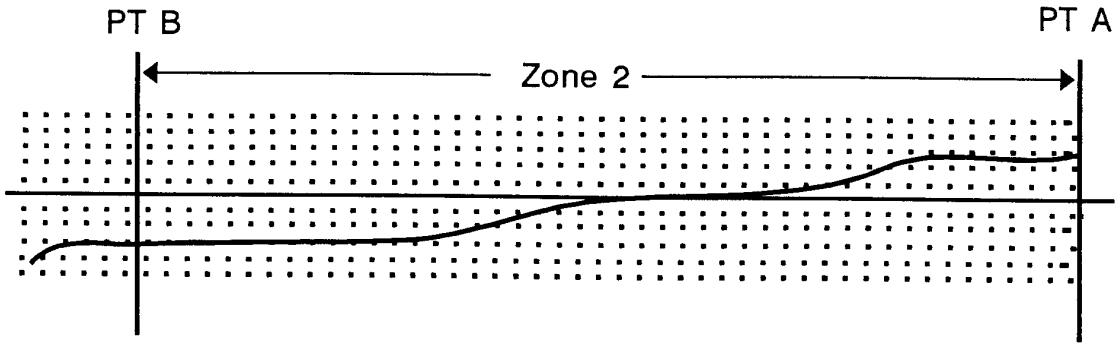
(c) Subtract result of step 2 from the preceding TCH + threshold MSL elevation (step 1). Insert this elevation value into the AFIS as the glide slope height.

b. Optimizing. Complete the glide slope transmitter modulation balance, phasing (if required), and optimize the glide slope path width and angle to within commissioning tolerances.

c. Data Collection. Conduct at least three glide slope approaches that produce similar trends in the AFIS zone 2 corrected error traces. This similarity is required to ensure accurate and repeatable results. On previously commissioned glide slopes, current AFIS ILS-3 evaluations can be used to determine whether or not application of this Order is feasible. Current ILS-3 data shall only be used provided the width and angle are within commissioning tolerances. Actual implementation will require a flight inspection documented in accordance with the provisions of this order.

d. Analysis. Refer to the AFIS zone 2 corrected error trace (Figure 1). If a skew in the trace is present, it is indicative of a change in the glide path on course locations throughout ILS zone 2 as viewed from the aiming point. This skewing may be caused by an incorrect AFIS aiming point reference elevation or be induced by environmental conditions. Each change in the reference elevation to correct the skew will require a re-evaluation**.** Once the skew is minimized, the average values of all runs determine the actual zone 2 BFSL glide slope angle and the glide slope **aiming point elevation.** When initial evaluation of zone 2 corrected error trace results in no skew and all requirements of FAA Order 8200.1A, Section 217 for glide slope commissioning are satisfactory, the procedures derived TCH values may be used for the RDH.

Figure 1. Skewed trace presented on an AFIS recording



e. Adjustments. The installation engineers shall make adjustments to the glidepath angle predicated on the average of the BFSL angle evaluations. Before making further evaluations, the AFIS glide slope height shall be reprogrammed to coincide with the new average glide slope **aiming point elevation**. Unusual glide slope siting conditions may produce bends or distortions in the glidepath. This condition can produce excessive glide slope aiming point elevation corrections and inconsistent glide slope angles. If the evaluation is to proceed under these conditions, use the BFSL angle as the reference and make both elevation and angle adjustments in half step increments.

f. Confirmation.

(1) Conduct additional AFIS glide slope evaluations until the glide slope **aiming point elevation** corrections repeat within 3 feet or less of each other on three separate flight inspection approaches. The average of these corrections, algebraically added to the initial AFIS glide slope height determined in paragraph 8a, is the final flight inspection glide slope **aiming point elevation** and the new AFIS glide slope height. If the final aiming point elevation is within ± 3 feet of the initial proposed value, the original value shall be used except as noted below.

> **Exception:** When applying the order to a CAT II or CAT III facility, it may be desirable to apply corrections within the 3 feet window due to tighter RDH tolerances. When the aiming point elevation is changed using this method, notify the Flight Inspection Operations Division of the actual aiming point elevation used. The elevation shall be documented on AMIS as the aiming point reference elevation for the facility.

(2) The final computed BFSL and announced angle shall be within ± .05 degrees of the desired commissioned angle. When the announced AFIS angle is within .03 degrees of the computed BFSL angle, the glide slope angle and origination point have been optimized. A zone 2 AFIS corrected error trace that has no skew relative to the zero microamp reference plot indicates the reference elevation has been optimized. (See Figure 1 for an example of a zone 2 AFIS corrected error trace that is skewing.)

(3) The Data Analysis Section will distribute the data to the appropriate flight inspection office (FIO), international flight inspection office (IFIO), procedures or military personnel. The RDH and GPI values shall be entered in the AMIS data.

g. Application.

(1) Flight Inspection. The zone 2 BFSL angle is valid, regardless of the glide slope height programmed into AFIS. The AFIS announced angle and zone 2 structure analysis are predicated on the AFIS glide slope height. These evaluations are not valid until the height is correct.

(2) Procedural Values. Use the new glide slope AIMING POINT elevation to compute the GPI, ARDH and RDH (TCH).

10. PERIODIC INSPECTIONS. There are no requirements to apply this order during periodic flight inspections. However, when the AFIS zone 2 corrected error trace is not centered about the zero microampere reference line, it indicates one or more of the following conditions: (1) Incorrect AFIS glide slope height (aiming point elevation). (2) Inaccurate AFIS runway position updates. (3) The glide slope angle is not linear in zone 2. If an AFIS error trace is not centered about the zero microamp line on an established glide slope facility, it is possible that the flight inspection evaluations could be improved if a new glide slope height/aiming point elevation, RDH, GPI, etc., is established.

11. CATEGORY I, II, AND III REFERENCE DATUM HEIGHTS.

a. CAT I. The RDH shall not be commissioned at a height which results in a wheel crossing height (WCH) of less than 20 feet or greater than 50 feet for the types of aircraft with the greatest glidepath-to-wheel height, normally expected to use the runway (see FAA Order 8260.34, Glide Slope Threshold Crossing Height Requirements). Military authorities may grant additional

exceptions on military use only glide slopes. Deviations from the height limits shall be approved by the National Flight Procedures Office, AVN-100, and the Technical Programs Division, AFS-400.

b. CAT II and III. The RDH, as determined by the application of this order, shall be commissioned at a height of 50 to 60 feet Deviations from these standards shall be approved by the National Flight Procedures Office (AVN-100) and the Technical Programs Division (AFS-400).

12. INFORMATION UPDATE. Any deficiencies found, clarifications needed, or suggested improvements regarding the contents of this order should be noted on FAA Form 1320-19, Directive Feedback Information. For your convenience, this form is included at the end of this order. If an interpretation is needed immediately, you may call the originating office for guidance. However, you should also use the FAA Form 1320-19 as a follow-up to the verbal conversation.

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APPENDIX 1. COMPUTATION OF THE BEST FIT STRAIGHT LINE

1. This appendix provides the methods for computing the BFSL. Some AFIS perform many or all of the following calculations automatically. The following mathematical procedure may be used when the complete AFIS solutions are not available. It is recommended that a programmable calculator or a computer be used when performing these calculations.

2. Symbols and Formulas.

θ_m = Measured angle as derived from the AFIS zone 2 corrected error trace.

X = Distance from a point on the localizer course; the AFIS aiming point; or a point directly abeam, if offset; to the sample point as derived from the corrected error trace.

0 = Perpendicular distance of the glide slope aiming point is offset from the localizer course if the offset is not zero.

$X_o = \sqrt{X^2 + 0^2}$ = Distance from the glide slope offset to the sample point. This value is used to determine Y and is required only if the glide slope aiming point is offset from the localizer course when analyzing old AFIS recordings where the glide slope coordinates were used for the aiming point.

$Y = [(\text{Tan } \theta_m) (X)]$ = Height of the sample point above the glide slope aiming point.

NOTE: Use X_0 if offset.

$\overline{X}$ = Average of all X distances.

$\overline{Y}$ = Average of all Y heights.

$x = X - \overline{X}$ (i.e., each individual distance value minus the average of all sample distances).

$\sum xY$ = The sum of all the products of x and Y.

$\sum x^2$ = The sum of all the squares of x.

$\sum \frac{xY}{x^2}$ = The tangent of the angle of the BFSL.

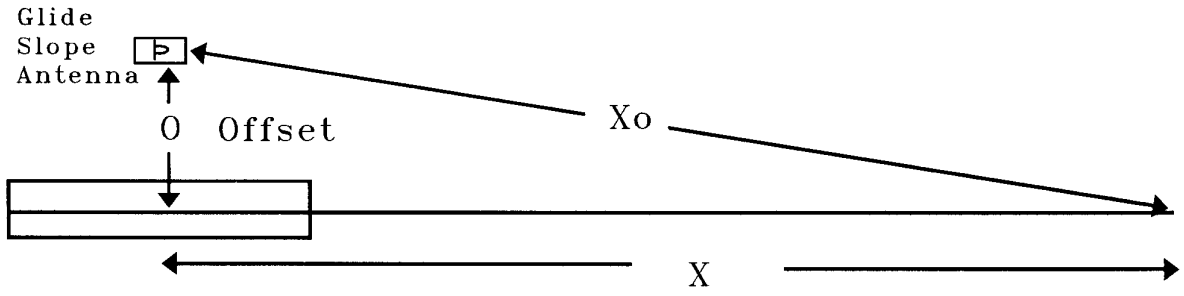
θ_b = Angle of the BFSL.

$\overline{Y} - [(\tan \theta_b)(\overline{X})]$ = Vertical height of the aiming point elevation must be adjusted to be in line with the extended BFSL. A minus value would indicate that the aiming point elevation must be lowered.

3. Symbol Illustration.

a. Plan View. Determine "X" and "X_0."

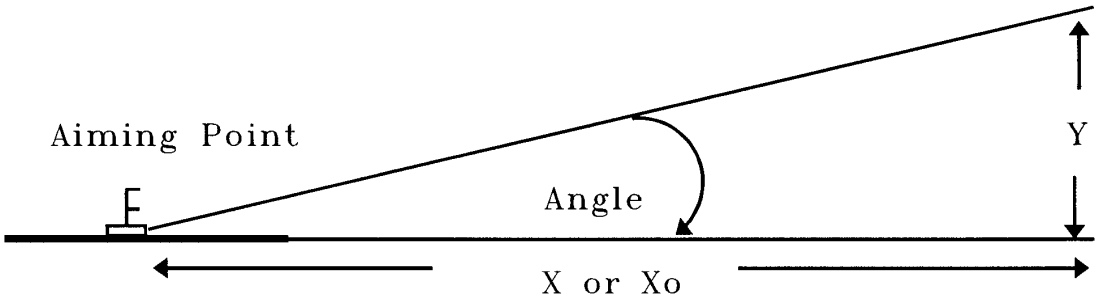
Figure 2



X_0 = Distance used to calculate Y when the offset is used for the aiming point.
X = Distance used to calculate Y when the CL is used as the aiming point.

b. Profile Views.

Figure 3



Determine Y by use of X or X_0 as appropriate

4. Preparing for the Calculation.

a. The calculations for BFSL angle, RDH, and GPI are made using an AFIS zone 2 corrected error trace. Identify and mark points "A" and "B" on this trace and divide this segment into 20 equal parts. A 10-point divider may be utilized for this task. The calculations for ARDH are automatically made by AFIS, using corrected error data taken from 6,000 feet from the threshold to point "C".

b. Record the MEAN angle about each sample point (i.e., plus or minus one-half the distance to the adjacent samples). Each mean angle measurement is recorded as a "light line" value. For analysis, each "light line" will equate to 1.0 (estimate to a tenth of a line for repeatability). "Light lines" are considered "plus" values when above the announced AFIS angle reference and "minus" values when below the reference.

c. Determine the horizontal distance "X" for each angle. Calculate the distance "X_o" if the AFIS aiming point was offset from the localizer course.

d. Compile all the preceding data and perform the following BFSL calculations.

5. BFSL Calculation. The following is an example of a zone 2 BFSL calculation.

- Distance from the point abeam the glide slope on the localizer centerline to the runway threshold = 1,075 feet.

- Height of the AFIS aiming point relative to the runway threshold = +1 foot higher than threshold elevation.

- Offset distance = 401 feet.

Sample#	θ_m	X	X_o	Y	x
Pt. "A"	3.00	25379	25382	1330	10402
2	3.00	24339	24342	1276	9362
3	3.00	23299	23302	1221	8322
4	3.00	22258	22262	1167	7281
5	2.99	21218	21222	1108	6241
6	2.98	20178	20182	1051	5201
7	2.98	19138	19142	997	4161
8	2.97	18098	18102	939	3121
9	2.97	17057	17062	885	2080
10	2.96	16017	16022	828	1040
11	2.95	14977	14982	772	0
12	2.95	13937	13943	719	- 1040
13	2.94	12897	12903	663	-2080
14	2.93	11856	11863	607	-3121
15	2.92	10816	10823	552	-4161
16	2.91	9776	9784	497	-5201
17	2.90	8736	8745	443	-6241
18	2.89	7696	7706	389	-7281
19	2.84	6655	6667	331	-8322
20	2.80	5615	5629	275	-9362
Pt. "B"	2.74	4575	4593	220	-10402

a. Results of BFSL Calculations.

$\overline{X} = 14977$ $\overline{Y} = 774.77$ $\sum x Y = 44483336$ $\sum x^2 = 833160000$

b. Tangent of BFSL Angle.

$$\frac{\sum xY}{\sum x^2} = \frac{44483336}{833160000} = 0.0533911 = \text{Tan of } 3.056 \text{ degrees.}$$

c. Determining the difference in height between the aiming point elevation and the BFSL extension.

$\overline{Y}$ - [(Tan θ_D)($\overline{X}$)] = Adjustment to height.
774.77 - [(0.0533911)(14977)] = -24.87 feet.

d. Determining the Commissioned RDH.

(1) Step 1. Multiply the tangent of the COMMISSIONED angle by the "distance" from the threshold to the AFIS aiming point. If the localizer is offset from the runway centerline, the "distance" shall be from a point abeam the AFIS aiming point to a point abeam the threshold on the commissioned final approach course.

(2) Step 2. Subtract the threshold elevation from the final AFIS aiming point elevation. Then, algebraically add the difference to the value determined in step 1. This value is the commissioned RDH and the published TCH for CAT I glide slopes.

e. Determining the GPI. Divide the RDH by the tangent of the commissioned angle.

f. Determining the Commissioned AFIS ARDH.

(1) Step 1. Obtain the announced "deviation in feet" of the BFSL at the threshold from the AFIS ILS-3 glide slope zone 3 data (e.g., PT-T = +2 (feet)). The "+ 2" is the distance in feet that this one evaluation differed from the commissioned mathematical value.

(2) Step 2. Algebraically add the deviation to the RDH obtained in Appendix 1, paragraph 5d, step 2 (e.g., 55 feet (RDH) + 2 = 57 feet (ARDH)).